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The aquatic macrophytes as refuge, nursery and feeding habitats for freshwater fish from Cabiúnas Lagoon, Restinga de Jurubatiba National Park, Rio de Janeiro, Brazil.

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ABSTRACT: The aquatic macrophytes as refuge, nursery and feeding habitats for freshwater fish from Cabiúnas Lagoon, Restinga de Jurubatiba National Park, Rio de Janeiro, Brazil. In several aquatic ecosystems, macrophyte areas represent important refuge, feeding or nursery habitats for aquatic organisms. These functional roles are attributed, mainly, to the associated food availability and to the structural complexity that promotes protection and a diversity of microhabitats. Considering the high density and richness of aquatic macrophytes at Cabiúnas coastal lagoon (RJ), the present study intends to identify the possible ways in which the fish assemblages use these habitats. Hence, some aspects of feeding habits, size distribution and life stages of the fish species were evaluated. During one year, fish were monthly sampled using seine nets in macrophyte banks from Cabiúnas lagoon. A total of 1,596 individuals from ten species were collected, the most abundant (97.3%) being the cichlid *Cichlasoma facetum* and the minute fishes *Hyphessobrycon bifasciatus*, *H. luetkenii* and *Poecilia vivipara*. Six species, that represented 97.9% of the total abundance, are classified in the omnivorous guild, suggesting that these environments are favorable to species with a high feeding plasticity. Moreover, the main feeding items consumed were highly available in the macrophyte banks from this same lagoon, demonstrating their role as feeding areas. Adult individuals were more abundant ($\chi^2=166.61$; $p=0.0001$), however the higher proportion of juveniles registered for medium to large-sized fish species suggests a use of the banks as nurseries. On the other hand, minute species occurred in high abundance, as both juveniles and adults, during the entire studied period, indicating an association with macrophytes throughout their ontogeny. In fact, these minute fishes are more prone to predation, indicating the macrophyte banks as favorable refuges.

Key-words: fish, aquatic macrophytes, coastal lagoon, Restinga de Jurubatiba.

RESUMO: As macrófitas aquáticas como habitats de refúgio, berçário e alimentação para espécies de peixes de água doce na lagoa Cabiúnas, Parque Nacional da Restinga de Jurubatiba, Rio de Janeiro, Brasil. Em diversos ambientes aquáticos, bancos de macrófitas representam importantes habitats para alimentação, refúgio ou berçário para organismos aquáticos. Esses papéis funcionais são principalmente atribuídos à disponibilidade de alimento associado e à complexidade estrutural, a qual promove proteção e diversidade de micro-habitats. Considerando a alta densidade e riqueza de macrófitas aquáticas na lagoa Cabiúnas (RJ), o presente estudo objetivou identificar possíveis maneiras de uso desses habitats pela comunidade de peixes. Para tal, aspectos do hábito alimentar, distribuição de tamanho e estágio de vida das espécies foram avaliados. Ao longo de um ano, os peixes foram mensalmente amostrados com redes de arrasto em bancos de macrófitas na lagoa Cabiúnas. Um total de 1596 indivíduos de 10 espécies foi coletado, sendo as mais abundantes (97,3%) o ciclídeo *Cichlasoma facetum* e os peixes de pequeno porte *Hyphessobrycon bifasciatus*, *H. luetkenii* e *Poecilia vivipara*. Seis espécies, que representaram 97,9% da abundância, pertencem à guilda de onívoros, sugerindo que esses ambientes seriam favoráveis a espécies com ampla plasticidade alimentar. Além disso, os principais itens consumidos são altamente disponíveis em bancos de macrófitas dessa lagoa, evidenciando seu papel como áreas de alimentação. Indivíduos adultos foram mais abundantes ($\chi^2=166,61$; $p=0,0001$), entretanto, a

maior proporção de juvenis registrada para espécies de médio a grande porte indica o uso dos bancos como berçário. Por outro lado, espécies de pequeno porte foram mais abundantes, tanto como adultos quanto juvenis, indicando uma associação com macrófitas ao longo de suas ontogenias. De fato, peixes de pequeno porte são mais propensos a predação, podendo os bancos de macrófitas serem considerados habitats de refúgio.

Palavras-chave: peixes, macrófitas aquáticas, lagoa costeira, Restinga de Jurubatiba.

Introduction

The coastal region located at the northeast of Rio de Janeiro (RJ) state is characterized by strong waves that constantly deposit sand on the coast that, in association with sediments originated from the rivers, has favored the development of sand barriers and lagoons (Panosso et al., 1998; Miranda et al., 2002).

The Cabiúnas coastal lagoon shows a lengthened profile, perpendicular to the coastline, with a sand barrier that separates it from the sea. During the years of 1993 and 2005 the lagoon remained closed and submitted to sporadic connections with the sea by high tides and waves. In fact, studies carried throughout that period indicated that the loss of a sea connection caused variations in the biological, chemical, and physical conditions of the lagoon, favoring the establishment of communities with demands for freshwater conditions (Branco, 1998; Esteves, 1998; Mello & Suzuki, 1998; Petrucio, 1998; Reis et al., 1998; Enrich-Prast et al., 2004; Sánchez-Botero, 2005). The lagoon dynamics became more influenced by continental and local variables; for example: the cover of aquatic macrophytes, the arboreal species of the flooded forests, in sanded stretches of the lagoon's branches, and the beach vegetation, primarily influenced by local climatic factors, high tides and waves (Scarano & Esteves, 2004). Regarding fish assemblages Reis et al. (1998) demonstrated, contrasting with a previous study by Aguiaro (1994), a higher dominance of freshwater species in relation to marine species favored, in addition to other factors, by the development of the aquatic macrophyte cover (Sánchez-Botero, 2005).

In several aquatic ecosystems of the world the aquatic macrophyte environments represent important refuge (Dielh & Eklov, 1995), feeding (Soares et al. 1986; Sabino & Stein, 1989; Dione & Folt, 1991; Whitfield, 1993; Chick & McIvor, 1997) or nursery habitats (Whitfield, 1993; Sánchez-Botero & Araujo-Lima, 2001) for fish. These functional roles of macrophyte banks are attributed,

mainly, to the associated food availability and to the structural complexity (Hampton, 2004; Warfe & Barmuta, 2004; 2006) that promotes reduction of water turbulence and visibility to predators and an increase in microhabitat diversity. Therefore, considering the high density and richness of aquatic macrophytes at Cabiúnas lagoon, this study aims to identify possible ways in which the fish assemblages use these habitats. To elucidate these questions, some aspects of feeding habits, size class distribution and stage of life (juveniles and adults) of the fish species were evaluated.

Study area

The Cabiúnas lagoon, located at the National Park of Restinga de Jurubatiba, Rio de Janeiro / Brazil (22°17' - 22°18' S and 41°39' - 41°40' W) has an elongated profile, perpendicular to the coast, with a sandbank that separates it from the adjacent sea, having also transversal branches from the main axis (Fig. 1). This lagoon has an area of 0.35 km², with maximum length of 0.9 km and 0.2 km in width, receiving a constant fluvial flow from a drainage basin of 45 km² (Panosso et al., 1998). This lagoon has an average depth of 2.5 m, with a pH of approximately 7.0, and has been classified as oligohaline. The conductivity and salinity values are affected by the continuous marine influence, due to percolation processes and, occasionally, when the sandbank is ruptured or over-tops the sea barrier when storms occur.

The dissolved oxygen values are considered normoxic (mean 7.18 mgL⁻¹) and the low nitrogen and phosphorus concentrations (total and dissolved) allow this system to be classified as oligotrophic (Petrucio & Faria, 1998; Farjalla et al., 2001; Enrich-Prast et al., 2004). A high density and richness of aquatic macrophytes (15 taxa) can be found at the lagoons littoral areas (Henriques et al., 1988; Esteves, 1998). The climate is hot and humid with rainy seasons in summer and spring, and dry periods in

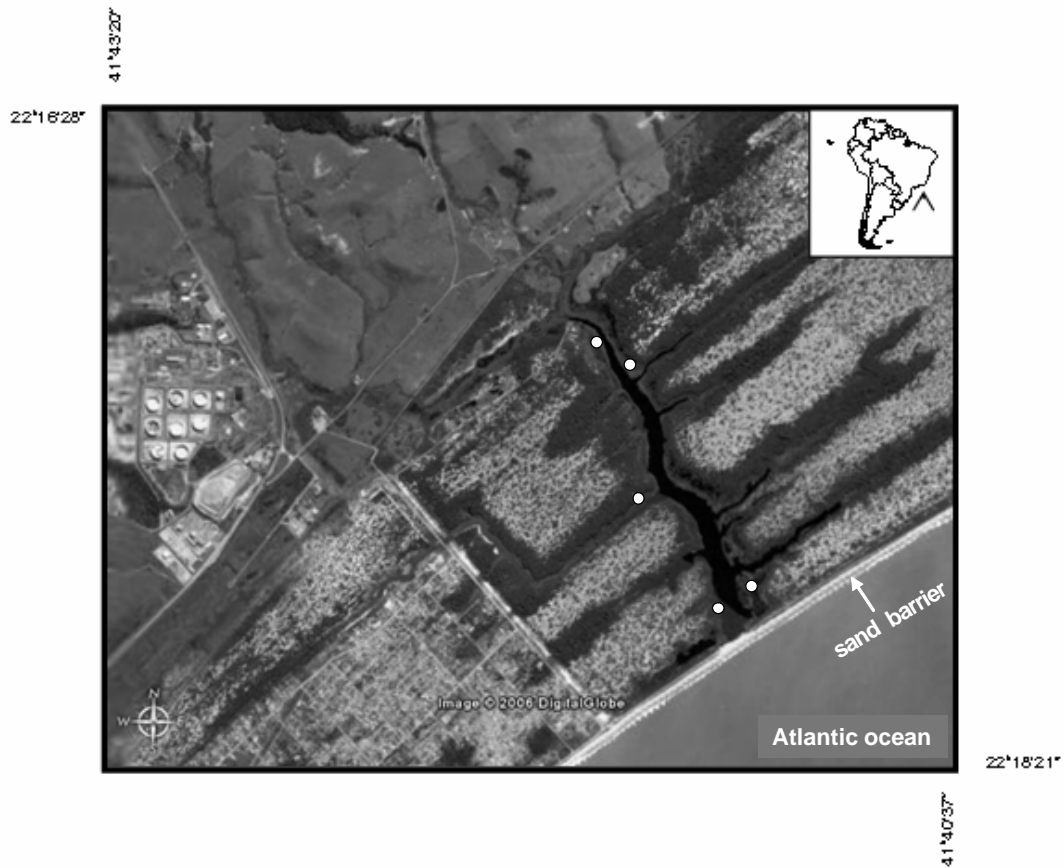


Figure 1: Sampled fish regions (with the points) at Cabiúnas Lagoon, National Park of Restinga de Jurubatiba, Rio de Janeiro / Brazil. Adapted from GoogleEarth Site (2007).

winter (Henriques et al., 1988). Monthly precipitation values registered in the study area between January of 1997 and September of 2004 show smaller variations in July, August, September (dry season) and higher variations in January, February and

March (wet season), with significant differences between them (paired t test, $t=2.97$; $p=0.020$). The average environmental temperature is approximately 25.4 °C (Evaporimetric Station Carapebus Lida, Macaé/RJ) (Fig. 2).

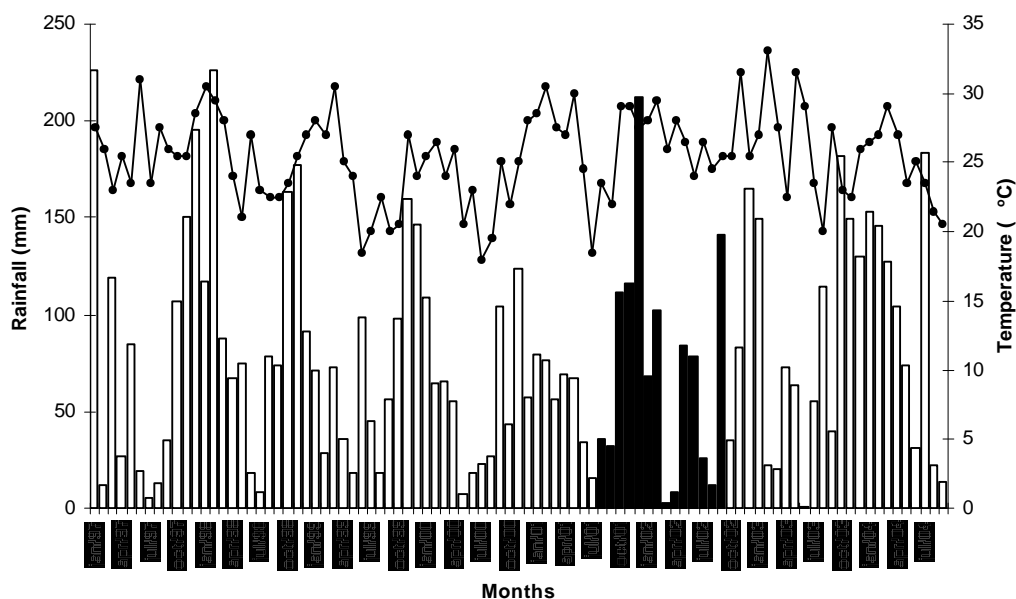


Figure 2. Precipitation cycles (bars) and environmental temperature (continuous line) in National Park of Restinga de Jurubatiba region. Black bars indicate precipitation values measured during the sampling period of the present study.

Material and methods

Between October of 2001 and September of 2002, monthly fish samplings were carried out in banks of aquatic macrophytes predominantly composed by *Typha dominguensis*, *Potamogeton stenostachys*, *Eleocharis interstincta*, *Salvinia auriculata* and/or *Eichhornia* spp.

In a standardized way, a seine net ("pícaré") of 1.5 x 1.2m and 5mm between adjacent knots was used for fish captures in aquatic macrophyte banks (24 drags per month) between 16:00 and 18:00 hours. The fishing effort was standardized, adding 43.2m² per month. Sampled fishes were fixed in 10% formalin and then preserved in 70% alcohol. They were identified through specialized bibliography, at the Fish Ecology Laboratory of the Federal University of Rio de Janeiro. Voucher specimens were registered at the National Museum of Rio de Janeiro (MNRJ). The sampling license number is 006/2003 (Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis - IBAMA).

Measurements of the standard length (cm) of each individual were taken. The minimum sexual maturity size (cm) was

determined through gonadal macroscopic examination, considering the smallest mature individual of each species. In order to obtain the smallest sexual maturity size of males of *Poecilia vivipara*, the smallest individual with developed gonopodium was considered, as indicated by Rosen & Bayley (1963). The Chi-square test was used to compare the frequency of adult and juvenile individuals of each species. Subsequently, to identify temporal variations of the standard length of the fish species, "Range Plots" were carried out. Feeding habits were evaluated through previous studies carried out at Cabiúnas lagoon.

Results

A total of 1,596 individuals from ten species were collected during the studied period, representing seven fish families and five orders. Of these, 10% are considered of marine origin and 90%, freshwater species. The most abundant species, that summed 97.3% of the total individuals caught, were: *Hyphessobrycon bifasciatus*, *Poecilia vivipara*, *Hyphessobrycon luetkenii* and *Cichlasoma facetum* (Tab. 1).

Table 1: Orders, families and species of fish captured in aquatic macrophyte banks at Cabiúnas lagoon between October 2001 and September 2002; Origin (marine - M; freshwater - F), abundance, first sexual maturation size (cm) and percentage of juvenile individuals. NR: not registered.

Order/Family/Species	Origin	Abundance	First sexual maturation size cm)	% of juvenil
Characiformes				
Characidae				
<i>Hyphessobrycon bifasciatus</i>	F	627	1.5	13
<i>Hyphessobrycon luetkenii</i>	F	342	1.7	15
<i>Oligosarcus hepsetus</i>	F	9	5.4	66.5
Curimatidae				
<i>Cyphocharax gilbert</i>	F	1	NR	0
Erythrinidae				
<i>Hoplias malabaricus</i>	F	19	6.2	58
Siluriformes				
Auchenipteridae				
<i>Trachelyopterus striatulus</i>	F	2	NR	100
Atheriniformes				
Atherinopsidae				
<i>Atherinella brasiliensis</i>	M	4	7.8	100
Cyprinodontiformes				
Poeciliidae				
<i>Poecilia vivipara</i>	F	469	1.7	31.6
Perciformes				
Cichlidae				
<i>Geophagus brasiliensis</i>	F	8	4.3	62.5
<i>Cichlasoma facetum</i>	F	135	3.8	87.5

The six remaining species showed an abundance of less than 20 individuals. The smallest captured fish measured 0.7 cm (*P. vivipara*) and the largest, 17.6 cm (*Hoplias malabaricus*). Adult individuals were dominant (73.4%), showing significant difference in relation to juveniles ($c^2 = 166.61$; $p = 0.0001$). Even so, 424 individuals (26.6%) from nine species occur in the macrophyte banks as juveniles; notably:

Atherinella brasiliensis (4 individuals), *Trachelyopterus striatulus* (2 individuals), *C. facetum* (118 individuals), *Oligosarcus hepsetus* (6 individuals), *Geophagus brasiliensis* (5 individuals) and *H. malabaricus* (11 individuals) (Tab. 1).

The monthly variation of the minimum, maximum and mean values of standard length indicated that juvenile individuals of almost all the species occur throughout the sampled periods (Fig. 3).

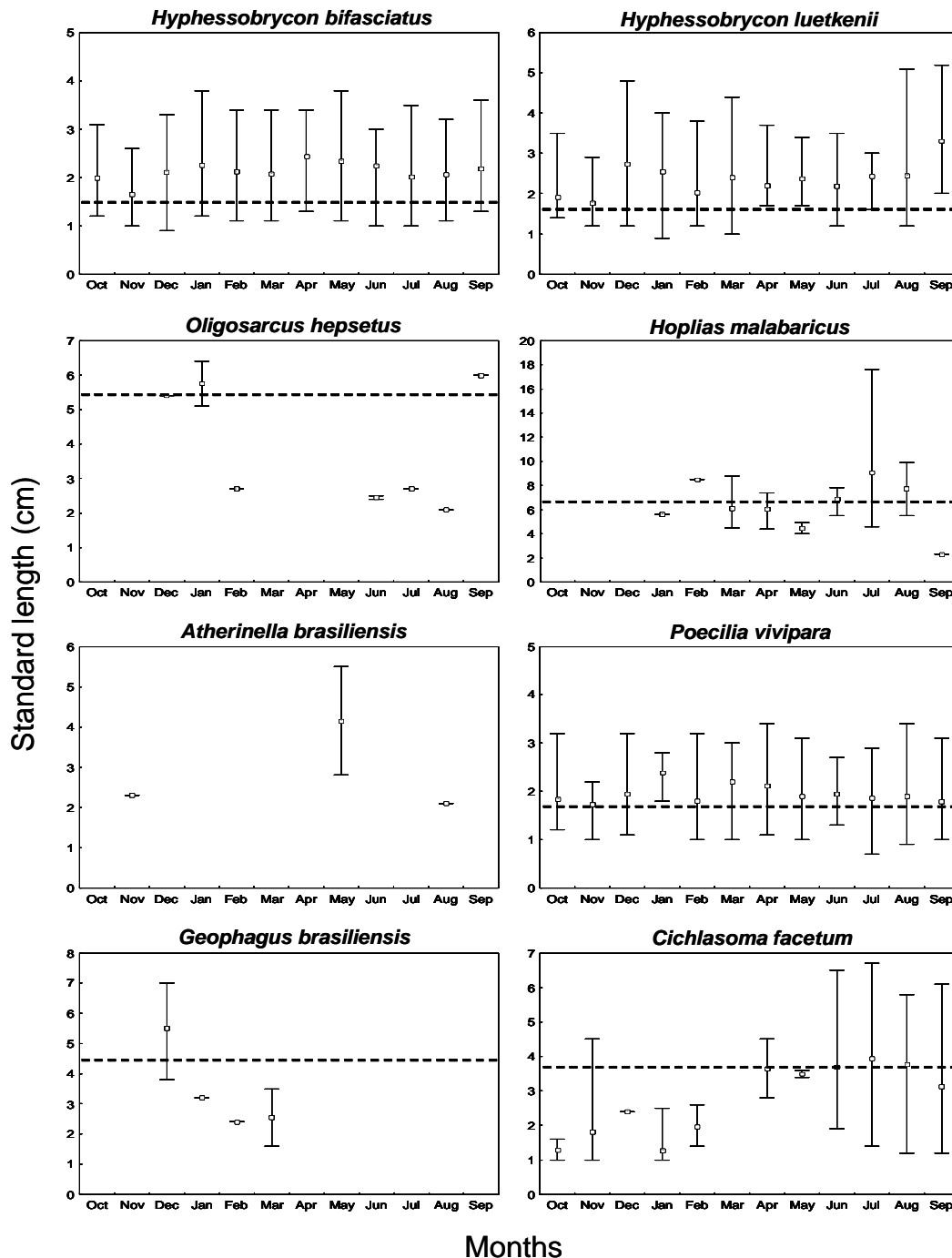


Figure 3: Monthly variation of the maximum, minimum and mean (\bar{y}) standard length values and first sexual maturation size (---) (cm) of fish species collected at Cabiúnas lagoon between October 2001 and September 2002.

Hyphessobrycon bifasciatus, H. luetkenii and P. vivipara showed mean standard length values higher than the first sexual maturity size during all the months of the year. On the other hand, adult individuals of Cichlasoma facetum were found only in the months of July and August; O. hepsetus in the months of December, January and September; H. malabaricus in February, June, July and August and, G. brasiliensis in December (Fig. 3). Only two juveniles and one adult individual of Trachelyopterus striatulus and Cyphocharax gilbert were collected, respectively. Because of the low abundances, the first sexual maturity size was not registered for these two species.

Considering feeding habits, 60% of the sampled species belong to the omnivorous

guild, consuming, primarily, zooplankton (Cladocera and Ostracoda), small clams (Gastropoda and Bivalvia), insect larvae and nymphs (Chironomidae and Odonata) and micro-algae (Tab. II). The other 40% of the species are divided between carnivores (30%) and detritivorous (10%), with the latter being represented by only one individual of C. gilbert. The carnivores may also be divided in two sub-categories: macrophagous (H. malabaricus and O. hepsetus), consuming fish and insects (larvae and adults) and microphagous (A. brasiliensis), that feed mainly on zooplankton and insect larvae (Tab. II). Considering the abundance distribution among feeding habits, the omnivorous guild represented 97.9% of the captured individuals.

Table II: Main food items consumed and trophic guilds of each fish species captured in aquatic macrophyte banks at Cabiúnas lagoon. Data according to: Aguiaro & Caramaschi (1998); Trivério-Cardoso (2004); Leitão et al. (unp. data).

Species	Main food items	Trophic guilds
H. bifasciatus	Cladocera; Ostracoda; Insect remains; Algae; Plant debris	Omnivorous
H. luetkenii	Cladocera; Gastropoda; Bivalvia; Algae	Omnivorous
O. hepsetus	Fish, Fish remains; Insect remains	Macrophagous Carnivores
C. gilbert	Desmidaceae; Detritus	Detritivorous
H. malabaricus	Fish, Fish remains; Hymenoptera; Insect remains	Macrophagous Carnivores
T. striatulus	Chironomidae larvae; Odonata nymphs; Insect remains; Ostracoda; Plant debris	Omnivorous
A. brasiliensis	Chironomidae larvae; Cladocera; Copepoda; Insect remains; Diatomaceae	Microphagous Carnivores
P. vivipara	Chironomidae larvae; Cladocera; Diatomaceae	Omnivorous
G. brasiliensis	Fish scales, Gastropoda; Bivalvia, Algae; Chironomidae larvae; Faeces	Omnivorous
C. facetum	Fish scales, Fish remains, Chironomidae larvae; Algae; Malacostraca	Omnivorous

Discussion

In coastal lagoons, the abundance, diversity and cover of aquatic macrophytes, influenced by environmental factors, such as depth, nutrient availability and salinity (Albaret & Ecoutin, 1989; Scarano & Esteves, 2004), directly affect their association with the fish fauna. At Cabiúnas lagoon the increment of freshwater characteristics favored the development in the abundance of aquatic macrophytes, potentially increasing refuge and feeding areas for the fish fauna. At this lagoon, macrophyte banks supply food resources to maintain both juvenile and adult fish. This situation was confirmed by the constant presence of

Chironomidae larvae, Cladocera, Ostracoda, Gastropoda and Bivalvia, besides insect remains, in the diet of most of the collected fish species. In fact, these invertebrate taxa are available in high abundances and species richness associated with aquatic macrophytes at Cabiúnas lagoon (Oliveira, 2002; Lopes, 2005). In the same studied area, individuals of H. bifasciatus and H. luetkenii were directly observed foraging in stands dominated by the submerged macrophytes Potamogeton stenostachys and the emergent Typha domingensis (Sérgio Lima, unpublished data). In addition, the dominance of fish with omnivorous habits (97.9% of the total abundance) in banks of aquatic macrophytes suggests that these

environments are favorable to species with elevated feeding plasticity. It is notable that, besides a rich macroinvertebrate fauna, a large presence of micro-algae, fungus and bacterial communities is associated with these habitats (Pompêo & Moschini-Carlos, 2003).

Other species collected in the aquatic macrophyte banks, in smaller proportion (<20 individuals) indicate that these habitats could support a predatory behaviour, for example, by *H. malabaricus* and *O. hepsetus*. At Cabiúnas lagoon, 33% of individuals of these species showed fish or fish remainders in their stomachs (Rafael Leitão, unpublished data). Still in smaller abundances, juvenile individuals of *Trachelyopterus striatulus*, *A. brasiliensis* and *G. brasiliensis* were captured, indicating partial association or accidental occurrence of these species with the aquatic macrophyte banks, since the higher percentage of adults was captured in limnetic zones (Sánchez-Botero, 2005).

The capture of only one individual of *C. gilbert* in aquatic macrophyte banks was considered accidental. In fact, detritivorous species (*C. gilbert* and *Mugil curema*) predominate in the limnetic zones of Cabiúnas lagoon (Aguiaro & Caramaschi, 1998; Sánchez-Botero, 2005) and juvenile individuals of *C. gilbert* possibly inhabit the lotic portion of the drainage basin. Despite literature indications that areas of aquatic macrophytes are environments with a high detritus output rate (Hickenbick et al., 2004), the expressionless contribution of detritivorous fish in the studied area could indicate that, in this case and specifically for this environment, these plants do not supply the nutritional quantities or qualities demanded by this guild. Although in estuarine environments the detritus biomass can be consumed by many fish species (Day et al., 1989) it is possible that the detritus originated from macrophyte decomposition are not palatable or are of a low digestibility, due to high-levels of cellulose and lignin (Cummins & Klung, 2006) for the detritivorous species that inhabit Cabiúnas lagoon. Besides *C. gilbert*, *T. striatulus* (also collected in low abundance) was shown by Reis et al. (1998) as being exclusively from areas influenced by riparian vegetation in this lagoon.

Aquatic macrophyte banks represent important shelters, mainly to small characiforms species (Bonetto et al., 1969,

1970; Araujo-Lima et al., 1986; Delariva et al., 1994., Meschiatti et al., 2000; Sánchez-Botero & Araujo-Lima, 2001; Vono & Barbosa, 2001), since they present less protective morphological and behavioral characteristics for avoiding predators. The present results corroborate this affirmation, since the lambaris of smaller size (*H. bifasciatus* and *H. luetkenii*) represent almost 60% of the sampled abundance. This same argument could be used for *P. vivipara* (30% of the abundance). This Cyprinodontiformes species has a limited swimming ability and forages next to the water surface (pers. obs.). In addition, apparently, this species does not show disruptive coloration or camouflage patterns, rendering itself more vulnerable to predators.

The present study results also suggest that aquatic macrophyte banks of Cabiúnas lagoon are potential nursery areas for fish fauna, as registered in other ecosystems (Whitfield, 1993; Sánchez-Botero & Araujo-Lima, 2001). Although the total proportion of adult individuals was higher than the proportion of young individuals, it is noteworthy that great part of the medium to large-sized fish species (*O. hepsetus*, *H. malabaricus*, *T. striatulus*, *A. brasiliensis*, *G. brasiliensis* and *C. facetum*) was captured as juveniles. Therefore, these species probably use macrophyte areas during the early periods of their lives and, when they become larger and enter adulthood, occupy limnetic zones. On the other hand, minute species, like *H. bifasciatus*, *H. luetkenii* and *P. vivipara*, occurred in high abundance, as both juveniles and adults, during the entire study period. This could indicate that the association with aquatic macrophytes exists throughout the ontogeny of small fish at Cabiúnas lagoon. Still concerning the temporal distribution of the standard lengths and the variability between them, the presence of individuals of the majority of the species from all age classes throughout the period possibly indicates a fish age distribution not influenced by climatic and hydrologic factors.

It is important to point out that the net used during this study could be considered selective for some sizes and/or species of fish that migrate between the limnetic and littoral zones of this lagoon (Sánchez-Botero, 2005). In addition to this, individuals smaller than 5mm had a smaller chance of being captured, due to the size of the net

employed, with this fact being able to limit or affect results, for example, diminishing the proportion of immature individuals of minute fishes. Moreover, although aquatic macrophyte banks have been dominated by the already mentioned plant species, it is pertinent to note that the plant richness depth variation, observed by Henriques et al. (1988) in this environment could affect fish vertical distribution. Similarly, resource availability such as luminous intensity (Sánchez-Botero et al., 2003), suspended particles and nutrients vary with depth (Spence, 1967). Finally, captures restricted to the twilight period could also have influenced the results, since some of these species can migrate trophically at night between the aquatic macrophyte banks and limnetic zones, as observed in other environments by Zaret (1984), Duncan & Kubecka (1995) and Smith et al. (2003). Therefore, it is pertinent to restrict the conclusions of the present study to the diurnal period.

The fish species have a range of different sizes, feeding habits and physiological demands in the aquatic macrophyte banks of Cabiúnas lagoon, demonstrating that this habitat has a wide range of niches and feeding resources. Similar characteristics were described in marginal lentic environments, indicating aquatic macrophytes as habitats that maintain a complex fish fauna structure (Merona & Bittencourt, 1993; Agostinho & Vazzoler, 1995; Araujo-Lima et al., 1995; Junk et al., 1997). Even though the ocean contacts to Cabiúnas lagoon might be ephemeral and influence some aspects of the structural dynamic of the fish fauna, it is important to state that the present carbon dominant autotrophic resources in this environment have lagoon and terrestrial origins (Aguiaro, 1999). This suggests that the energy flow that held the establishment of a fish fauna of continental origin is favored by the development of the aquatic macrophyte cover. Besides the autotrophic importance, the simple role as substratum to a wide range of bacterial, algal and invertebrate communities could explain the presence of a great part of the fish fauna, with different feeding habits in these habitats. Finally, the present study demonstrates the role of the structural complexity of macrophytes as a refuge for freshwater fish, for both minute species and juveniles of medium and large-sized ones.

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